REGENERATION OF APPENDAGES AND MOLTING AMONG THE THYSANURA

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The Apterygota is a very primitive group of insects, none of them reaching the high morphological specialization that is common among the Pterygota. While several species of apterygotan insects are being studied, this report will be confined largely to two species, *Thermobia domestica* Pack., and *Lepisma saccharina* L.[1] The Thysanura, according to Crampton (1928) are among the more advanced of the apterygotan insects. Crampton's classification of the Apterygota will be followed in this paper.

It is well known that the Apterygota are ametabolous in their development, that is, the young are essentially like the adults in structure and undergo no radical morphological changes. While a few structures of the adults are lacking among the newly hatched nymphs, the most conspicuous one is the absence of scales until the third molt when the young nymphs become sparsely clothed with scales.

A common belief among entomologists is that the Thysanura, at least, do not molt directly as most insects do, but that the cuticula is shed in small bits at a time and more or less continuously. However, this is not the case with the species under observation. The molts are definite and complete, even on legs, antennae, and cerci. The cuticula splits along the dorsal midline of the thorax and head, and the insect emerges through this opening leaving the exuvium intact and in one piece, including the appendages. Generally the exuviae are eaten by the newly emerged individuals, or others, shortly after being cast off, except after the first and second larval instars. This habit, which is common among many insects, persisted even though fish meal and dried beef were available in the diet.

The frequency of molting of *Thermobia domestica* and *Lepisma saccharina* depends very much on the rate of metabolism, which in turn in influenced by the environmental conditions; a temperature of 37° C. and a relative humidity of 75 per cent being near the optimum for the former, and a temperature of about 28° and rela-

[1] A more complete report, the results of an investigation covering two years, of the ecology and biology of *Thermobia domestica* is being prepared for publication.

tive humidity of 90 per cent being near the optimum for the latter. Under such conditions, especially with *Thermobia,* molting is frequent with both nymphs and adults. The time between molts is quite variable, but roughly among adults can be expected to occur on an average of 20 to 25 days at 37° and 40 to 50 days at 22° for *Thermobia.* Among the immature stages at 37° the interval between molts, after the first, which occurs when the nymphs are about one day old, gradually lengthens with age from about 5 to 6 days to that of the adult. At 22° the time before the first molt requires approximately 4 days, the second instar requiring about 11 days. The intervals between the last two or three molts preceding death of the adults is frequently shortened and may approximate 10 days.

The number of molts that the Thysanura undergo is indefinite. Spencer (1930) suggests that approximately 14 instars are passed in the immature stages of the fire brat, but some of the specimens under observation by the writer have passed beyond that number and are definitely still immature. The writer knows of no criterion that can be said to definitely indicate maturation, but it is suggested that the length of the ovipositor may furnish a useful measure with the females. The writer has considered specimens definitely adult, once eggs are produced, but oviposition cannot be taken as a criterion since high temperature seems to be essential for egg production although development will occur at much lower temperatures. Size cannot be used as a measure of reaching adulthood as some individuals are much smaller than others when the first eggs are laid, even when reared in identical environments. Since the adults molt throughout life it is evident that no definite numbers of molts can be assigned to a given species.

Apparently it has not been recognized that the Thysanura molt throughout life at frequent intervals, although the Collembola are credited with this phenomenon (Folsom, 1926; Comstock, 1926; Imms, 1929). Metcalf and Flint (1932) make no reference to adult molting of Thysanura and Collembola, and in a table indicate that adult molting does not occur. Imms definitely states that the Collembola and Ephemeroptera are the only forms that molt after maturation. Spencer (1930) reports that apparently *Thermobia domestica* can go through life molting if necessity arises. Wellhouse (1928) states that *Campodea staphylinus* Westw. molts the same as other insects, but may continue to molt after reaching the adult stage. However, Imms following Grassi says, *Campodea* has only a single fragmentary ecdysis during its development. Appar-

ently Spencer and Wellhouse believe that adult molting of these insects is unusual. Sanborn (1919) claims to have worked out the life history of *Lepisma saccharina* in some detail, but makes no reference to the adults molting. Raff (1933) working with *Ctenolepisma lineata* Fabr. speaks of six to seven instars in the life cycle. Folsom (1920) in a general paper definitely states that the Apterygota molt at frequent intervals throughout life and that the number of molts is indefinite. However, in his text (1926) no reference is made to adult molting of Thysanura, while the Collembola and mayflies are so mentioned. Cornwall (1915) in studying a lepismatid in India, tentatively identified as *L. saccharina,* found that the adults molted as well as the nymphs. The writer (1933) emphasized the fact that normally the Thysanura molt throughout life. Recently Adams (1934) reported molting among the adults of *T. domestica.*

Several writers (Tillyard, Metcalf and Flint, Imms) refer to certain insects as Plecoptera, Odonata, and Ephemeroptera as having 20 or more molts. Imms assigns 23 for mayflies and a single molt for *Campodea* and *Japyx.* My records show that the Thysanura, in certain favorable environments at least, commonly exceed this number. If all this is true the variation among the species of Apterygota in number of molts is far greater than any known cases among the Pterygota.

A few records of the regeneration of appendages are available (Lubbock, 1870; Sanborn, 1919), but apparently it is thought to be confined to the nymphs. The writer has observed regeneration in adults as well as nymphs of the greater portion of the antennae, lateral and caudal cerci, and at least the tibia and tarsi of the legs. Complete regeneration is evident following a molt, unless molting only a few days following injury, and not partial as frequently seen among the Arachnida.

Molting throughout life, after maturation as well as before, is common to the apterygotan insects, crustacea, and chilopods,[2] and perhaps other groups of Arthropoda. Regeneration of jointed appendages is common throughout the molting periods of apterygotan insects, crustacea, chilopods, diplopods, and arachnids, and perhaps other groups of Arthropoda. The method of fertilization as given by Spencer (1930) for *Thermobia domestica* and, partially confirmed by the writer, is more primitive than is known among ptery-

[2] The information regarding chilopods and diplopods was furnished through the kindness of Dr. R. V. Chamberlin at the University of Utah.

gotan insects. The males go through a "love dance" performance in the presence of the females, during which a spermatophore is dropped. This later is picked up by the female and the transfer of sperm accomplished. This, according to Spencer, is suggestive of that occurring among the chilopods. These facts are suggestive of a close relationship or, at least, of common ancestry of these arthropodan forms.

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